COAL PARTICLE FLOW PATTERNS FOR O_2 ENRICHED LOW NO_X BURNERS

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This project involves a systematic investigation examining the effect of near-flame burner aerodynamics on standoff distance and stability of turbulent diffusion flames and the resultant NO_x emissions from actual pulverized coal diffusion flames. Specifically, the scope of the project is to understand how changes in near-flame aerodynamics and transport air oxygen partial pressure can influence flame attachment and coal ignition, two properties essential to proper operation of low NO_x burners. Results from this investigation using a new 2M tall, 0.5m in diameter combustor designed to evaluate near-flame combustion aerodynamics in terms of transport air oxygen partial pressure (Po_2), coal fines content, primary fuel and secondary air velocities, and furnace wall temperature furnish insight into fundamental processes that occur during combustion of pulverized coal in practical systems.

In the 2M furnace, a combustion ratio greater than 1 was required for stable operation, where the combustion ratio is defined as the ratio of the combustion air velocity (V_c) to primary jet velocity (V_t). Increasing this ratio increases flame stability and promotes flame attachment. Increasing Po_2 and/or fines fraction in the pulverized coal also enhances combustion stability producing attached flames that were otherwise detached. NO_x emissions are reduced by up to 50% through flame attachment. The degree of oxygen enrichment necessary to produce attached flames decreased with increasing wall temperature. For always-attached flames, increasing Po_2 and the fraction of fines had little impact on total NO emissions. NO emissions increased with increasing combustion ratio for always-attached flames due to increased mixing between the primary fuel and combustion air jets, thereby increasing the local oxygen content.

Increasing fines content and velocity ratio reduced flame standoff distances for always-detached flames and produced stable detached flames that were otherwise unstable. However, neither fines nor transport air oxygen partial pressure greatly affected total NO emissions from always-detached flames. Increasing the velocity ratio did reduce total NO emissions for always-detached flames through reduced flame detachment and resultant premixing in the near-burner region.

For always-attached flames, increasing the combustion ratio stretches the flame producing a narrowed flame neck approximately 2 primary jet diameters below the burner. Decreasing the transport air oxygen partial pressure to 17% at high Θ caused the narrowed flame neck to destabilize forming intermittent flamelets. Further reducing Po_2 to 12% produced a stable dual flame. The dual flame consisted of a short flame attached to the burner and a long detached flame with a flame front 18" below the burner. Observations of similar dual flames have not been found in published literature. The dual flame can be compared to staged combustion where one creates a primary fuel rich combustion zone followed by a second combustion zone for burnout, however supplemental OFA is not required with the dual flame.

In this project, laser Doppler velocimetry and phase Doppler anemometry were also used to probe the detail motion of particles and gas in particle-laden jets. The first goal was to investigate the effect of velocity ratio on particle dispersion in coaxial particle-laden jets. The second goal was to explore the effect of particle size distribution on the motion of particles in particle-laden flows loaded with binary mixtures of two different sized particles.

The study was performed for three velocity ratios, VR = 0, 1.0, and 1.5, and for two different sized particles: 25-micron and 70-micron glass beads with a solids loading of 0.5. LDV measurements show that the distribution of particles across the jet becomes more uniform with decreasing particle size for the same velocity ratio. Moreover, for the same particle size, the distribution of particles across the jet becomes more uniform as the velocity ratio increases. Flow visualization revealed that as the velocity ratio increases, the instantaneous particle structure tends to become wavier and less asymmetric. It was also observed that for VR = 1.5 the radial dispersions for both particles sizes are significantly enhanced.

An investigation with binary mixtures of 25-micron and 70-micron particles in downward pipe flow demonstrated that the addition of finer particles leads to an increase in the mean velocity of the coarse particles near the pipe. Moreover, the presence of the fine particles also enhances the velocity fluctuations of the coarse particles. The presence of coarse particles, however, does not affect the motion of the fine particles. Measurements of gas-phase velocity in the binary mixtures were also performed as a function of the mass fraction of the fine particles. Result from these measurements show that for the same total loading the dampening in the gas turbulence for the binary mixture consisting of 50% fines is less pronounced than a monodisperse suspension of coarse particles.

Results from this study also indicate that an increasing mass fraction of the finer particles in the mixture leads to a decrease in the radial mean velocity for the coarse particles. This effect is due to an increase in the resistance for the coarse particles to move in the flow as the number of fine particles is increased. Moreover, the ratio of the radial to axial mean velocity for the coarse particles decreases with increasing mass fraction of fine particles, implying a reduction in the radial dispersion of the coarse particles.

List of Journal Articles and Presentations:

Ogden, G.E., Budilarto, S.G., Sinclair, J.L., Wendt, J.O.L., "Comparison of Velocity vs. Momentum for Stabilizing Turbulent Natural Gas Flames" Presented at the 2000 Spring Meeting, AFRC, Newport Beach, CA, June 1-5, 2000.

Budilarto, S. G. and Sinclair, J.L., "Velocity Ratio Effect on Gas and Particle Motion in a Two-Phase Coaxial Jet", Presented at the 2000 Annual AIChE Meeting, Los Angeles, CA, November 2000.

Budilarto, S.G., and Sinclair, J.L., "Effect of Velocity Ratio on Co-axial Jet Flow Behavior", Presented at the International Conference on Multiphase Flow, New Orleans, LA, May 2001.

Budilarto, S.G., and Sinclair, J.L., "Effect of Particle Size on Particle Flow Patterns in Co-axial Jets", Presented at the 2001 Annual AIChE Meeting, Reno, NV, November 2001.

Budilarto, S.G., and Sinclair, J.L., "Flow Visualization of Particle-Laden Coaxial Jet Flow", Presented at the 2002 Annual AIChE Meeting, Indianapolis, IN, November 2002.

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